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E7.6-10189
CR-146287

# MULTIPLE RESOURCE EVALUATION OF REGION 2 U.S. FOREST SERVICE LANDS UTILIZING LANDSAT MSS DATA

(E76-10189) MULTIPLE RESOURCE EVALUATION OF REGION 2, US FOREST SERVICE LANDS UTILIZING LANDSAT MSS DATA Quarterly Progress Report, 1 Dec. 1975 - 29 Feb. 1976 (Colorado Univ.) 27 p HC $4.00 CSCL 08F

N76-18610

Unclas G3/43 00189

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March, 1976, QUARTERLY PROGRESS REPORT
For Period December 1, 1975 – February 29, 1976

NASA CONTRACT NAS 5–20948

Prepared for
GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland 20771

23760

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|---|---|---|
| 1. Report No. Type II, No. 4. | 2. Government Accession No. | 3. Recipient's Catalog No. |
| 4. Title and Subtitle MULTIPLE RESOURCE EVALUATION OF REGION 2, U.S. FOREST SERVICE LANDS UTILIZING LANDSAT MSS DATA | | 5. Report Date February 29, 1976 |
| | | 6. Performing Organization Code |
| 7. Author(s) Dr. Paula V. Krebs and Staff | | 8. Performing Organization Report No. |
| 9. Performing Organization Name and Address Institute of Arctic and Alpine Research University of Colorado Boulder, Colorado 80309 | | 10. Work Unit No. |
| | | 11. Contract or Grant No. NAS5-20948 |
| 12. Sponsoring Agency Name and Address Mr. Ed Szajna National Aeronautics and Space Administration Goddard Space Flight Center ~~Greenbelt, Maryland 20771 Code: 902~~ | | 13. Type of Report and Period Covered Type II December 1, 1975 to ~~February 29, 1976~~ |
| | | 14. Sponsoring Agency Code |

15. Supplementary Notes
Prepared in cooperation with the Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, Indiana; and U.S. Forest Service, Region 2, Denver, Colorado.

16. Abstract

LANDSAT MSS data has been classified into a vegetation map of the Southern San Juan Mountains Planning Unit using the modified clustering approach (LARSYS). This is the third classification to be generated for the study area. The previous two classifications were not sufficiently accurate to meet Forest Service needs. Eleven training areas were used in the final classification. A precision correction was preformed on the LANDSAT data set being used for digital analysis to permit accurate overlay with Forest Service resource data. A master set of diazos has been made for positive and negative images of stero LANDSAT frames. An analysis for landforms and geomorphic features of the diazo composites has begun. Work has begun on a "results tape" which will include vegetative and topographic data, and can be incorporated into the Forest Servicd computer facility. The results tape will give Forest Service personnel a variety of display options for vegetation and topographic parameters.

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|---|---|
| 17. Key Words (Selected by Author(s)) diazo composites, modified clustering, results tape, precision correction, digital classification, photoingerpretation, vegetation, geomorphic features, training areas | 18. Distribution Statement |

| 19. Security Classif. (of this report) | 20. Security Classif. (of this page) | 21. No. of Pages | 22. Price* |
|---|---|---|---|
| Unc. | Unc. | 22 | |

*For sale by the Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia 22151.

TYPE II THREE MONTH PROGRESS REPORT

For the period beginning December 1, 1975 and ending February 29, 1976.

A. Title: Multiple Resource Evaluation of Region 2, United States Forest Service Lands Utilizing LANDSAT MSS Data

LANDSAT Contract No. NAS 5-20948

B. Principal Investigator: Dr. Paula Krebs
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GSFC Identification No. 376

D.1. Vegetation mapping

The major thrust of the past three months has been devoted to the digital processing of LANDSAT data for a satisfactory vegetation classification. In November an unsupervised classification was generated fo. the entire planning unit. Data from every fifth line and column was used to define twelve spectral classes. This classification was considered to be unsatisfactory after examination revealed lack of necessary information content for the U.S. Forest Service purposes.

A modified clustering approach was then decided upon in the hope of obtaining better results (Hoffer, et al 1974; Fleming et al 1975). For this second classification seven training areas were used, five training areas east of the Continental Divide in the Rio Grande National Forest (September quarterly progress report), and two training areas on the west side of the Continental Divide in the San Juan National Forest (Figure 1). The two training areas west of the Continental Divide were added to represent vegetation classes not found or not adequately represented in the other five training areas. Training area #6, Chromo Bend, contains oak-ponderosa pine cover types with some Douglasfir and meadow. Training area #7, Squaretop Mountain, is a glorious mixture of classes from pure conifer, to coniferous/deciduous to pure aspen.

Each training area was independently clustered into the "optimum" (minimum Wilkes-Lambda) number of spectral classes (called cluster classes) using LANDSAT MSS data. A statistics deck for twenty-three spectral informational classes was pooled from the cluster classes of all seven training areas. These twenty-three classes were derived on the basis of spectral separability, but have been tentatively identified by photointerpretation of each training area for the cluster classes. The statistics deck of the twenty-three spectral informational classes was used to classify the entire study area. Resultant map products in line printer output were:

Six 7½' U.S.G.S. quadrangles selected for intensive study displaying:

a) each of the twenty-three spectral informational classes as a different symbol

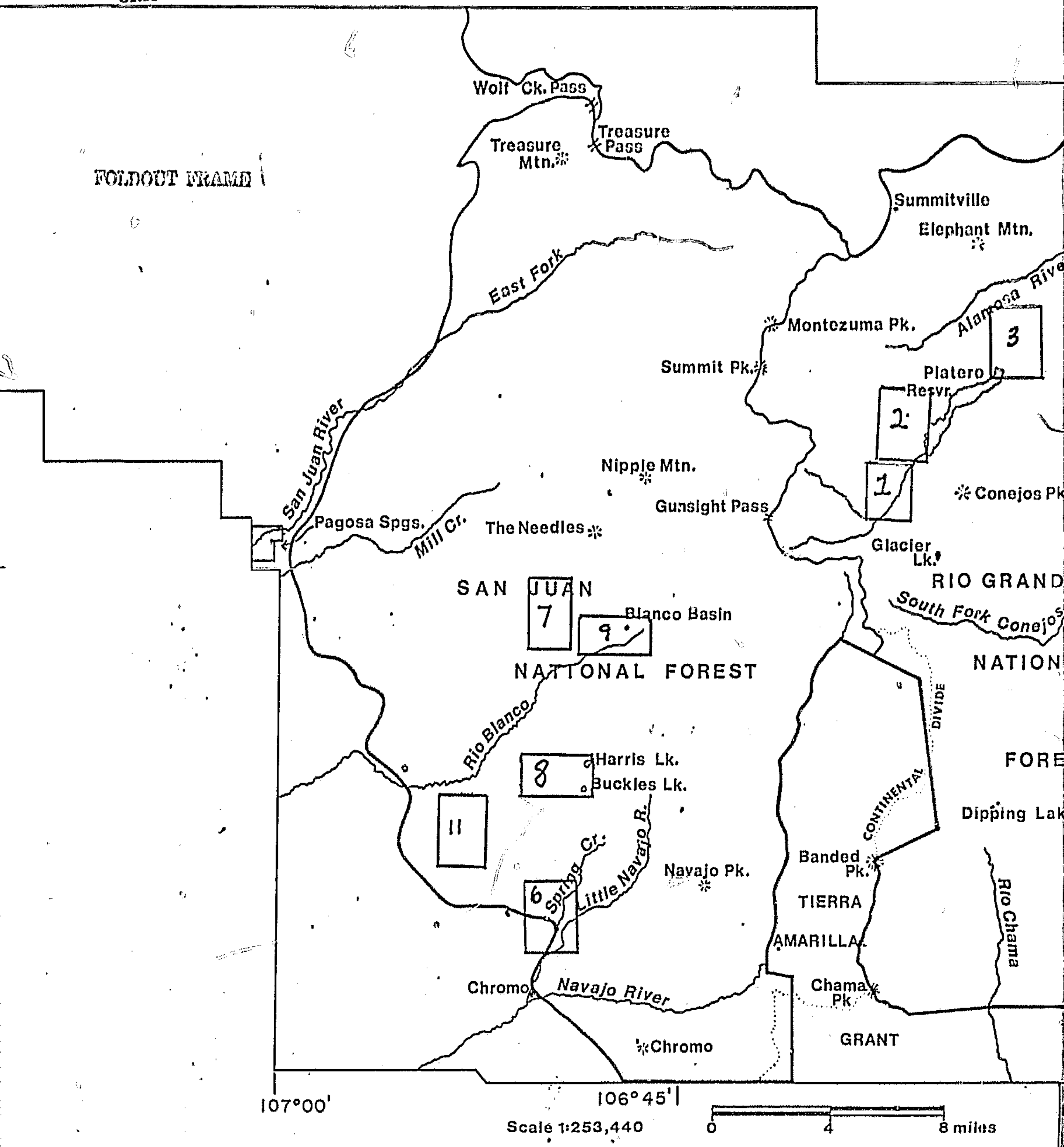
b) eight informational classes as a different symbol. Informational classes are formed by grouping spectral informational classes to illustrate specific features of interest.

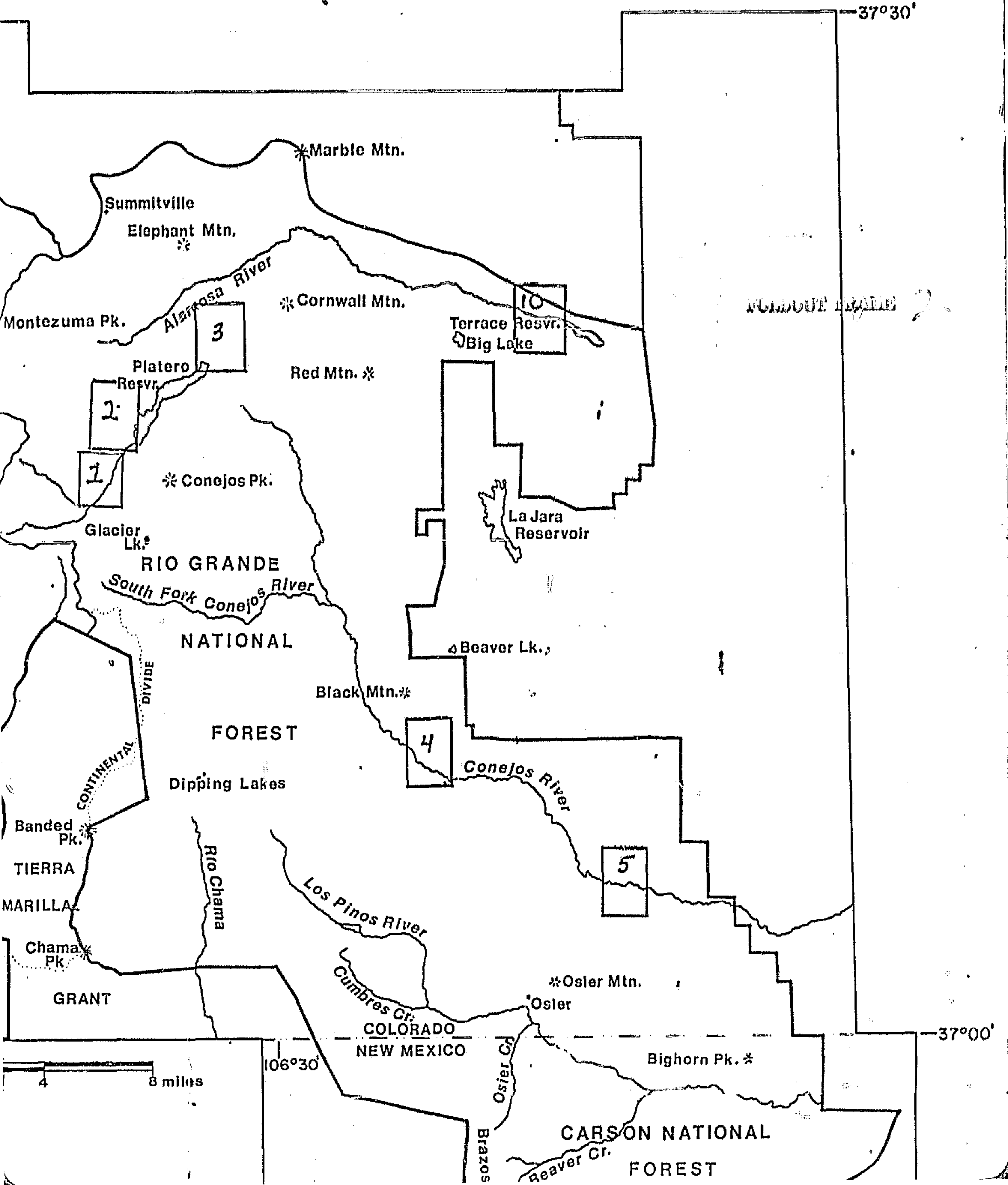
Forty-seven test fields in two of the intensive quadrangles (Platoro and Chromo NE), were selected for a preliminary quantitative evaluation of the classification. The test field performances are shown in Table 1. Certain problems within the classification were emphasized by the quantitative evaluation. Ponderosa pine is being confused with the mixed coniferous forest informational class (mix). There is also a problem in separating the aspen category from the oak category.

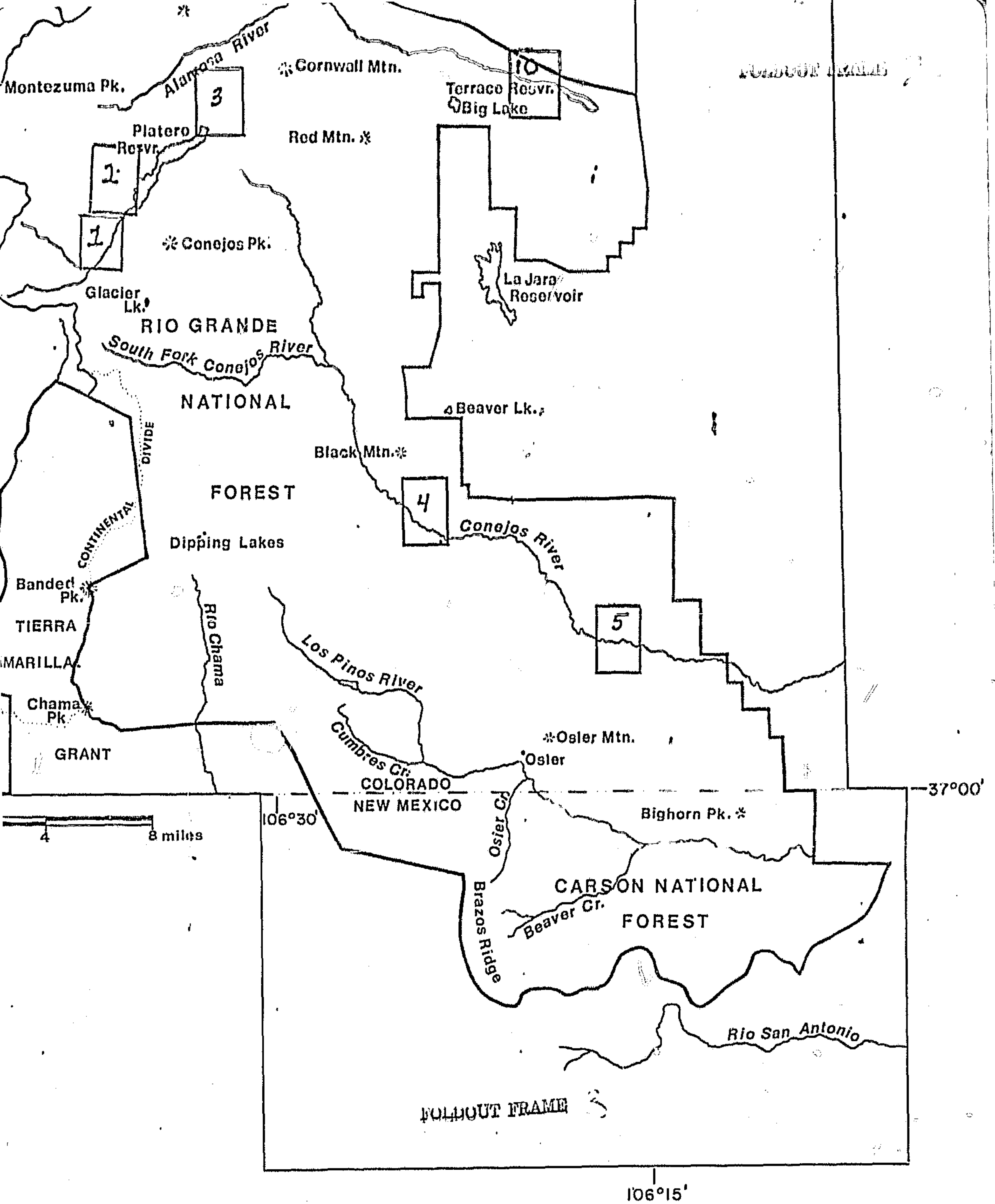
C. Problems Encountered.

No problems were encountered during this reporting period.

Figure 1. Training areas used in the vegetation classification of the Southern San Juan Mountains Planning Unit. The training areas were selected to represent the cover types found in the Planning Unit.


Wolf Ck. Pass
Treasure Mtn.
Treasure Pass
Summitville
Elephant Mtn.
Alamosa River
East Fork
Montezuma Pk.
Summit Pk.
Platero Resvr.
3
2
1
San Juan River
Nipple Mtn.
Gunsight Pass
Conejos Pk
Pagosa Spgs.
Mill Cr.
The Needles
Glacier Lk.
SAN JUAN
7
9
Blanco Basin
RIO GRANDE
South Fork Conejos
NATIONAL FOREST
NATION
DIVIDE
Rio Blanco
Harris Lk.
8
Buckles Lk.
FORE
CONTINENTAL
11
Little Navajo R.
Spring Cr.
Dipping Lak
Navajo Pk.
Banded Pk.
6
TIERRA
AMARILLA
Rio Chama
Chromo
Navajo River
Chama Pk.
Chromo
GRANT
107°00'
106°45'
Scale 1:253,440
0
4
8 miles


37°30'
FOLDOUT FRAME 2
Marble Mtn.
Summitville
Elephant Mtn.
Alamosa River
Cornwall Mtn.
Montezuma Pk.
3
10
Terrace Resvr.
Big Lake
Platero Resvr.
Red Mtn.
2
1
Conejos Pk.
La Jara Reservoir
Glacier Lk.
RIO GRANDE
South Fork Conejos River
NATIONAL
Beaver Lk.
DIVIDE
Black Mtn.
FOREST
4
Conejos River
CONTINENTAL
Dipping Lakes
Banded Pk.
TIERRA
MARILLA
Rio Chama
5
Los Pinos River
Chama Pk.
Osier Mtn.
GRANT
Cumbres Cr.
Osier
COLORADO
NEW MEXICO
37°00'
106°30'
Bighorn Pk.
4
8 miles
Osier Cr.
CARSON NATIONAL
FOREST
Brazos
Beaver Cr.




FOLDOUT FRAME

Table 1. Test Class Performance for a preliminary evaluation of the first classification of the Planning Unit. 1/

| | No. of Samples | Percent Correct | Number of Samples Classified into: Bare | Grass | Oak | Aspen | P. Pine | Mix | SF | Water | Bad Data |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Grass | 171 | 65.5 | 7 | 112 | 21 | 11 | 18 | 2 | 0 | 0 | 0 |
| Oak | 458 | 66.2 | 0 | 2 | 303 | 80 | 54 | 19 | 0 | 0 | 0 |
| Aspen | 827 | 56.3 | 0 | 16 | 256 | 466 | 37 | 43 | 7 | 0 | 2 |
| P. Pine | 342 | 18.4 | 0 | 0 | 6 | 76 | 63 | 174 | 23 | 0 | 0 |
| Mix | 56 | 44.6 | 0 | 0 | 1 | 10 | 0 | 25 | 20 | 0 | 0 |
| SF | 1121 | 97.3 | 0 | 0 | 0 | 0 | 0 | 17 | 1091 | 2 | 11 |
| Water | 223 | 92.4 | 0 | 0 | 0 | 0 | 0 | 1 | 16 | 206 | 0 |
| TOTAL | 3198 | | 7 | 130 | 587 | 643 | 172 | 281 | 1157 | 208 | 13 |

1/ Classification to be run again using additional training statistics

A qualitative evaluation of the classification displaying twenty-three spectral informational classes identified major problem areas. This evaluation used field data and aerial photography (NASA Mission 75-101) as resource information. The aerial photography was superimposed on the line printer output of the classification using a Baush and Lomb zoom transfer scope. The spectral informational class for water was good. Two classes for Engelmann spruce/subalpine fir distinguished between high and moderate densities (crown closure). Major problem areas identified were:

- confusion between oak and aspen on the west side of the Continental Divide
- confusion between moist meadows and aspen
- all shrubs classified as oak
- sparse density conifer (including krummholz) classified as ponderosa pine
- some bare rock areas displayed as high reflectance bad data
- deciduous-coniferous forest included in all classes from pure Douglasfir through pure aspen.

A classification with such low accuracy and with confusion among the classes is of little use to the Forest Service.

In early January Mike Fleming of the LARS team, was in Colorado for several days. During this visit the problems of the classification and probable causes were discussed. The probability that some of the spectral classes from the training fields had been improperly identified led to improper grouping of spectral classes. Another major cause of error was insufficient representation of the cover types of interest in the training fields.

As a result of the discussions, four additional training areas were selected, three west of the Continental Divide and one east of the Continental Divide (Figure 1). These training areas were added to include cover types which were being confused in the spectral informational classes. Training area #8, Harris Lake, was selected to represent the oak/aspen interface; training area #9, Upper Rio Blanco, included meadow and a range of coniferous/deciduous forest compositions; training area #10, Terrace Reservoir, contained the mix categories as well as ponderosa pine, and sage which had not been represented in the other training fields; training area #11, Spiler Canyon, has a wide range of densities of ponderosa pine and oak. All eleven of the training areas were used to generate training statistics for the third classification.

All training areas were photointerpreted from NASA Mission 75-101 (scale 1:100,000) by the INSTAAR team. This photointerpretation is the best possible for this particular mission. The color infrared aircraft photography was supplemented by U.S.G.S. 7½' topographic maps, extensive field work in the Southern San Juan Mountains Planning Unit, and a background of ecological knowledge of the species concerned. All work was compared and checked by three members of the team, each experienced in photointerpretation. Differences of photointerpretation among team members centered on 10% of the total density and 10%

density of component species differences in the mixed classes. Film characteristics of color, hue, and texture were used in photo-interpretation for cover types in the study area as shown in Figure 2. This diagram can provide a base for other photointerpreters using this particular coverage. Stereo coverage using a Mimo-3 light table with a Bauch and Lomb stereoscope gave the best mapping results. Boundaries were then transfered to a U.S.G.S. 7½' topographic map base using a Bauch and Lomb zoom transfer scope. The final cover type map for each training area is on a mylar base to permit overlay onto 7½' maps and printout at a scale of 1:24,000.

Each of the training areas was clustered as explained above. Each cluster class in each training area was described using aircraft coverage and the mylar cover type maps. The INSTAAR team made a ten day trip to LARS to work with the LARS analysts in the final phases of this analysis. Several iterations were necessary before the twenty-five final spectral classes were defined. Two quadrangles, Platoro and Chromo NE were used during the analysis to check the classification using various combinations of the spectral classes. The entire study area has been classified for the third time using these spectral classes. A preliminary visual evaluation of this classification shows it to be better than the first two classifications.

The third classification shows the maximum spectral information which can be obtained using this data set with the current technology available at LARS. There still seems to be some variation in the cover types represented by some of the spectral classes from one part of the study area to another. It is possible that additional training areas could more clearly define the spectral characteristics of the cover types being considered. However, many training areas would be necessary to account for the spectral variation due to slope aspect, slope steepness, vegetation maturity, geographic distribution of plant communities, moisture differences, phenological differences, and the multitude of factors which effect the spectral response of vegetation. It is doubtful that the time and money required to select additional training areas, incorporate them into the training statistics for classification, and to define the classes would greatly improve the classification. The other alternative would be to classify each part of the study area separately using a different set of training statistics for each classification. Again, when computer aided analysis is done for small geographic areas the cost/return increases per unit area and becomes unprofitable (Hoffer, et al, 1975).

The twenty-five spectral classes have been broadly defined on the basis of the cluster class identifications (Table 2). The INSTAAR team will check the classification throughout the study area using aircraft coverage. Each spectral class will be described in detail including geographical and ecological variation. These detailed descriptions will give the Forest Service a better feeling for the classification and make it more useful.

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Figure 2. Film characteristics of cover types. Identification of cover types by air photointerpretation is based in part on the color and texture of each cover type. No one color or texture describes one cover type. Each color on this diagram represents a point on a continuous spectrum. The color of a cover type falls within a portion of the spectrum. The number and color descriptions are based on National Bureau of Standards ISCC-NBS system of color designations. Key textural characteristics of each cover type are given in parantheses.

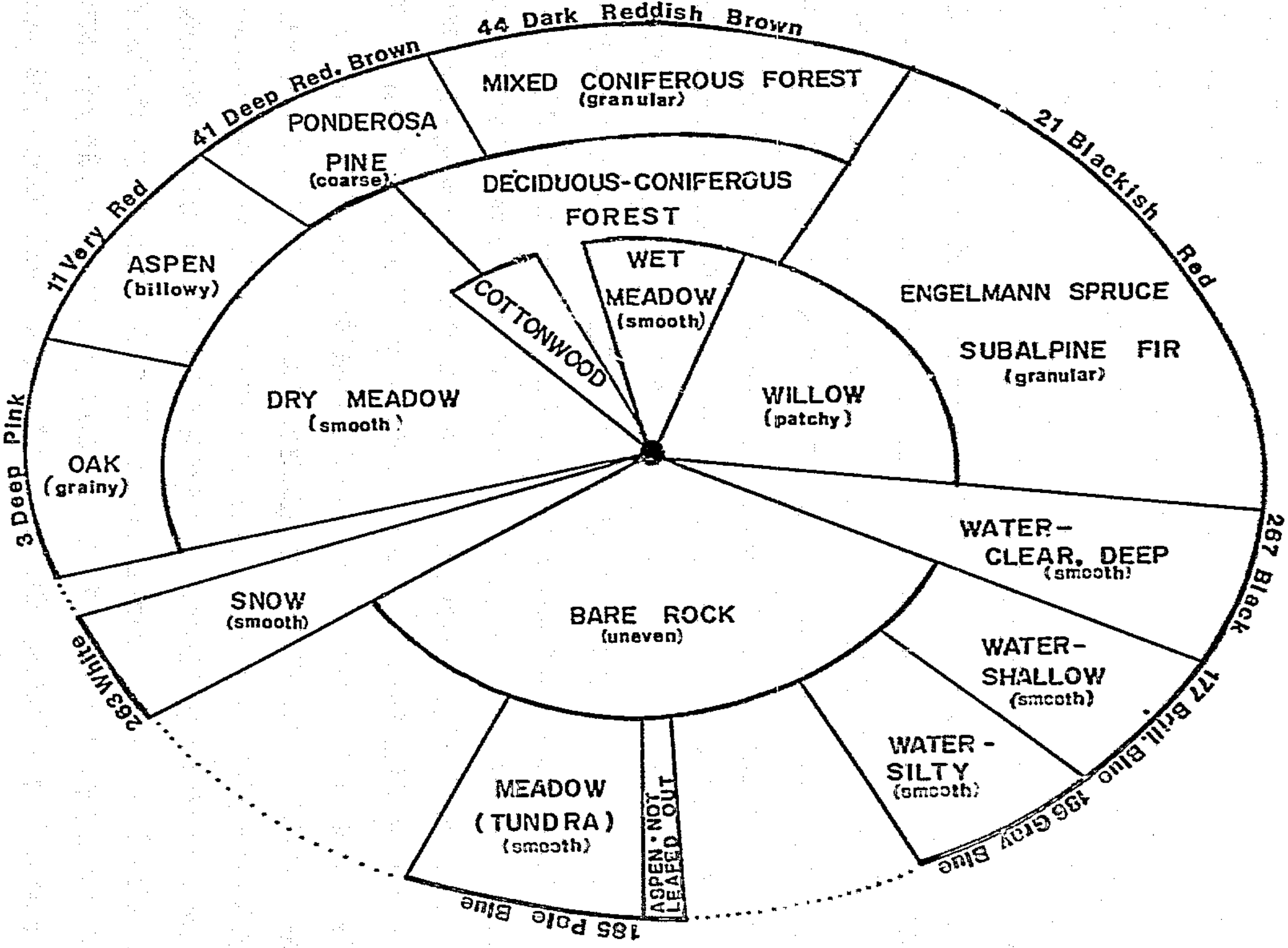
44 Dark Reddish Brown
41 Deep Red. Brown
11 Very Red
3 Deep Pink
263 White
185 Pale Blue
186 Gray Blue
177 Brill. Blue
267 Black
21 Blackish Red
MIXED CONIFEROUS FOREST
(granular)
PONDEROSA PINE
(coarse)
ASPEN
(billowy)
OAK
(grainy)
DECIDUOUS-CONIFEROUS FOREST
COTTONWOOD
WET MEADOW
(smooth)
DRY MEADOW
(smooth)
WILLOW
(patchy)
ENGELMANN SPRUCE
SUBALPINE FIR
(granular)
WATER-
CLEAR, DEEP
(smooth)
WATER-
SHALLOW
(smooth)
WATER-
SILTY
(smooth)
BARE ROCK
(uneven)
SNOW
(smooth)
MEADOW
(TUNDRA)
(smooth)
ASPEN - NOT LEAFED OUT

Table 2. Spectral class identifications based on photointerpretation.

| Spectral class | Description |
|---|---|
| A | water, some shadow |
| B | 80-100% spruce/fir |
| C | 70-80% spruce/fir |
| D | 70-80% spruce/fir, Douglasfir; with up to 10% aspen |
| E | 70-90% spruce/fir, Douglasfir; with 10-20% aspen |
| F | mix class, predominately coniferous with some deciduous |
| G | low density conifer with grass, includes some edge effect |
| H | low density conifer with grass, includes krummholz |
| I | rocky, dry grassland |
| J | mix class, approximately half deciduous, half coniferous |
| K | 100% aspen |
| L | 100% aspen |
| M | 100% aspen with small meadows |
| N | 100% aspen with small meadows |
| O | mix class, predominately deciduous |
| P | moist grassland |
| Q | sparse aspen ($<$ 50%) with grass and rock understory |
| R | sparse deciduous, includes $<$50% aspen, cottonwood, willow |
| S | moist grassland, irrated pasture |
| T | dry grassland, in tundra-late snowbank areas |
| U | dry grassland |
| V | rocky, dry grassland, less than 30% density |
| W | bare rock and soil, exposed |
| X | bad data |
| Y | bad data |

The process involving several classifications and manipulation of the spectral classes for training statistics emphasized the need for the involvement of personnel who have a good ecological background, are familiar with the study area through field work, and who have an understanding of the principles involved in digital processing. These people must work closely with the ultimate users to determine their needs, and with the analysts to see that the needs are understood and fulfilled as far as the systems and technology will allow. This becomes especially important in areas where there is a complex mosaic of vegetation types.

D.2. Results tape.

The anticipated final product of this project is a "results tape" which will be incorporated into the Forest Service computer facilities in Fort Collins, Colorado. Each individual forest has a terminal to these facilities. The Forest Service has already developed the R-2 mapper (U.S. Forest Service 1973) software which can handle multiple levels of resource data. The results tape will be put into a format so that it can become an on-line item through the R-2 mapper software. The results tape would allow the Forest Service to use the efforts of this project in day-to-day activities. This tape will include three channels of topographic information: slope aspect in twelve categories, slope percent in six categories, and elevation in 100 meter increments; and one or more channels of vegetation information derived from LANDSAT data. There will be additional channels available for the Forest Service to add their own digitized data such as soils or geology, or even management parameters. The results tape will give the Forest Service versatility in display options for the parameters available on tape.

In discussions with Forest Service personnel over the past two years it has become evident that there is a wide variety of needs for vegetation and topographic information through the various offices of the Forest Service. Regional offices often need a map of generalized vegetation, the planning effort needs to consider all vegetation types for management decisions, and the day-to-day operations of the forest use specific cover types and topographic parameters. The twenty-three spectral informational classes (two additional classes are bad data) with detailed descriptions will allow the Forest Service personnel to group classes into generalized cover types, or to select the cover types of emphasis, or to combine vegetation with topography such as all aspen on southern exposures above 2300 m (7545 ft.). This gives a variety of display options at the command of the user.

The multichannel data set used by LARSYS is in the Multispectral Image Storage Tape format (MIST). The LARSYS MIST format was selected

for the results tape since it is basically a byte oriented format which is common to many film output and plotter devices and allows direct checking of the tape by other LARSYS processors. The tape can be easily converted to pure byte format by stripping off the LARSYS identification record and calibration bytes. Basic planning and initial coding has been completed. Test output should be obtained by the first of March, 1976.

## D.3. Precision correction.

The initial processing of LANDSAT data for geometric correction and rescaling only approximates the scale of the U.S.G.S. 7½' topographic maps. There is about 1½% horizontal compression and 2% vertical stretch. This is about ½ mile shift per quadrangle. The Forest Service needs to have the vegetation and topographic information exactly match their base maps so that additional data can be added using Forest Service maps. This involves political boundaries and planning unit boundaries which are not easily digitized. Precise overlays are also necessary for accurately locating the test fields from field data on the greyscales. LARS has the capability of performing a precision correction on a set of LANDSAT data. The precision correction has been completed for the study area. The third classification was done using the precision correction, and all further work involving test field locations and Forest Service interpretation will use output from the precision correction.

## D.4. Landform Mapping
Diazo Color Composites

Effort during this report period was primarily devoted to the creation of a master set of diazo transparencies for the color enhancement of the LANDSAT imagery. Because the human eye can distinguish 350,000 continuous color variations as opposed to only 200 shades of gray, a color display of LANDSAT data is optimum for manual interpretation (Warrington and Ryerson, 1974). Only two standard color composites are produced by the National Air Photo Library whereas other band color combinations may better enhance particular features of interest. Diazo color composites provide an easy and inexpensive means to manipulate other composite combinations. Three colors (usually the additive primaries red/blue/green, or the subtractive primaries cyan/magenta/yellow) are used with three of the four LANDSAT bands (usually bands 4, 5, and 7). When both positive and negative transparencies are combined, 48 different three band/three color combinations are possible.

The main advantage of the diazo process is the cost. Ready made color composite transparencies from NASA cost $12 each. For each color

composite not already on file, an additional $50 is assessed. A set of the 18 diazo color separates needed to make all 48 color composites costs about $5.50. Materials used in experimentation to determine the correct exposures cost $30. Even with the additional cost of the original positive and negative transparencies, diazos are less expensive and far more flexible for different interpretation needs than the standard composites.

The main disadvantage of diazo color composites is that some resolution is lost. The separate bands are difficult to register with one another. The layering effect when viewed with magnification confuses the interpretations to some degree. Because diazos are another step beyond the original data, some information and resolution is lost in the translation. However, the cost and flexibility of diazos far outweigh the slight loss of resolution.

The diazo process involves film coated with a compound sensitive to ultraviolet light. The emulsion side of a LANDSAT transparency is placed on the emulsion side of the diazo film and is exposed to an ultraviolet light source. The film is then "developed" with ammonia vapor. For this effort, a model 101 Diazo Printer and a model 202 Developer from the Arkwright-Interlaken, Inc. were utilized, courtesy of the U.S. Geological Survey, Air Photo Division, Denver Federal Center.

Cyan, magenta, and yellow diazo transparencies were created for both positive and negative transparencies of bands 4, 5, and 7 from LANDSAT images 1425-17190, September 21, 1973, and 2222-17020, September 1, 1975. Exposure times vary depending on the relative density of the LANDSAT frames of interest, and thus, a small amount of experimentation is necessary. In general, cyan diazos will require about a half minute longer exposure than yellow diazos, and exposures for magenta diazos will be nearly twice that of yellow. For the mountainous, well vegetated southern San Juan Mountains, "light" images such as positive band 7 and negative bands 4 and 5 require exposure times between one and five minutes. Because diazo film can not be overdeveloped, prolonged exposure to ammonia vapor will not turn the image uniformly dark. Thus, development time was no problem.

A preliminary analysis of all 48 composite combinations was conducted to determine probable utility in landform mapping. The most useful composites are those with good color contrast as well as sufficient color variation. Even though all three colors were used in each composite, some combinations consisted of subtle variations of only one or two colors in the spectrum and yielded little more information than the original black and white transparencies. Other combinations were too dark or poorly resolved.

Because of the long exposure times required for negative band 7, the resolution of these diazos was very poor and composite combinations involving them are generally useless. Most combinations using two negative images decreased color contrast. The best combinations

consisted of a positive band 7, a positive band 4 or 5, and a negative band 4 or 5. The resulting ten "best" color composites will be analyzed in greater detail during the next period.

With the recent acquisition of several cloud-free early winter images (2259-17073/October 8, 1975; 2276-17013/October 25, 1975; 2294-17012/November 12, 1975) subtle differences in the topographic expressions of landforms may be revealed through snow enhancement. The light snowstorms during October and November, 1975 were followed by warm, sunny days. This allowed differential melting of south and west-facing slopes while north and east-facing slopes remained snow covered. The sharp contrast between these slope aspects delineate subtle topographic expressions not visible on other LANDSAT images. Stereo pairing of adjacent early winter images allows easier identification of topographic features such as large landslides and drainage patterns. These early winter images will be evaluated further in the next few months.

D.5. Projected activities.

The next three months will be spent finalizing the activities of this project. The third classification, using the modified clustering approach with eleven training areas, will be evaluated for the entire study area using aircraft coverage. This evaluation will give a qualitative estimate of the accuracy, and point out the spectral informational classes which are causing problems. A detailed description for each of the twenty-three spectral informational classes will be written from the visual examination of the classification and the study area. The detailed descriptions will consider the variation of cover types in each class with geographic, topographic, and ecological variations throughout the study area. If there are any glaring errors which could be corrected through recombination of statistics from the cluster classes, this will be done. Otherwise, this classification is final.

Test fields will be selected to quantitatively evaluate the classification using three methods:

1) automatic selection of 2X2 pixel test fields on greyscales of six quadrangles, photointerpreted from aircraft coverage as reference data,

2) manual selection of large homogenous areas from aircraft coverage,

3) combination of automatically selected data point grid and field data as outlined in the third quarterly report. These fields must be relocated due to the shift resulting from the precision correction.

The automatic evaluation of the classification will be made using all three methods of test field selection to give a comparison of the methods.

There are several options as to the form the final classification will have when it is incorporated into the results tape. Discussions will be held with the Forest Service as to which options will be the most useful. The results tape will be finished and incorporated into the Forest Service computer facility at Fort Collins, Colorado.

The evaluation of the landform mapping system will be finished. The best diazo combinations of LANDSAT data will be analyzed. A landform map will be produced using the best features of the diazo combinations.

A cost/benefit of LANDSAT data and computer-aided analysis techniques will be derived based on this project.

Workshops and discussions will be held with the Forest Service in regional and forest offices to aid in the understanding of remote sensing, an evaluation of the current project, and the development of future applications of remote sensing within the Forest Service.

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E. Significant Results.

There are no author identified significant results during this reporting period.

F. Publications.

There have been no publications or public presentations during this reporting period.

G. Recommendations.

None.

II. Aircraft Data.

Receipt of the two film types of NASA Mission 75-101 has been invaluable to this study. The more than 50% overlap provides good stero viewing on the small scale coverage which has been very much appreciated. The small scale coverage is being used to select test areas throughout the study site for evaluating the computer generated vegetation classification. This coverage is also the main resource data being used for the detailed descriptions of the twenty-three spectral classes. The larger scale coverage was used by LARS to identify the cluster classes of each of the training areas.

I. Data Use.

| | |
|---|---|
| *Value of data allowed | $1,536 |
| Value of data ordered | $1,400 |
| Value of data received | $1,400 |

*With authorization from Dr. Price monies were shifted to enable us to purchase the needed aircraft coverage.

Imagery account #G23760 adjusted ballance $134.00
CCT account #GB3760 adjusted ballance $400.00
Aircraft account #GW3760 adjusted ballance $66.00

J. Funds Expended.

| | | |
|---|---|---|
| First Quarter | | $ 14,334 |
| Second Quarter | | $ 10,031 |
| Third Quarter | | $ 18,068 |
| Fourth Quarter | | |
| Salaries and wages | $ 7,576 | |
| Indirect costs and supportive services | $ 3,469 | |
| Travel | $ 1,566 | |
| Materials | $ 850 | |
| Subtotal | $ 13,461 | |
| Subcontract | | $ 61,876 |
| | Total | $118,570 |